

e. *High silicon self-diffusion coefficient in dry forsterite* (H. Fei, C. Hegoda and D. Yamazaki/Misasa, S. Chakraborty and R. Dohmen/Bochum, M. Wiedenbeck/Potsdam, H. Yurimoto/Sapporo, S. Shcheka and T. Katsura)

The plastic deformation of minerals at high temperature is controlled by diffusion or dislocation creep. Diffusion creep is governed by the diffusion of atoms through the volume and along grain boundaries, and dislocation creep is also believed to be rate-limited by diffusional processes if dislocation climb is involved. Silicon is the slowest diffusion species in most mantle minerals and therefore expected to limit the creep rates. Olivine is the main constituent mineral in the upper mantle and forsterite is the Mg-rich end-member of olivine. Hence, the Si self-diffusion coefficient (D_{Si}) in forsterite is essential for understanding the upper mantle rheology. Previous studies of D_{Si} in olivine and forsterite at ambient pressure showed discrepancies of ~ 2 -3 orders of magnitude with those estimated from deformation experiments. Hence, it is necessary to reexamine D_{Si} . In this study, we measured D_{Si} in dry forsterite at 1600 and 1800 K and 0-13 GPa. We obtained a much higher D_{Si} , and it well explains the high dislocation climb rates in deformation experiments.

After polishing with diamond powder and a colloidal silica solution forsterite single crystals were coated with 300-500 nm of ^{29}Si enriched Mg_2SiO_4 films and covered by 100 nm of ZrO_2 films. The samples were pre-heated at 1273 K for 2 h to remove water in the coated films. The pre-cooked samples were then annealed at 1600 and 1800 K, 0-13 GPa and different duration (0-43 h) for diffusion. Water contents in the samples were determined to be less than 1 $\mu\text{g/g}$ before and after annealing by infrared spectroscopy. The diffusion profiles were obtained by secondary ion mass spectroscopy and values of D_{Si} with surface roughness calibration were determined by fitting the profiles to the solution of Fick's second law.

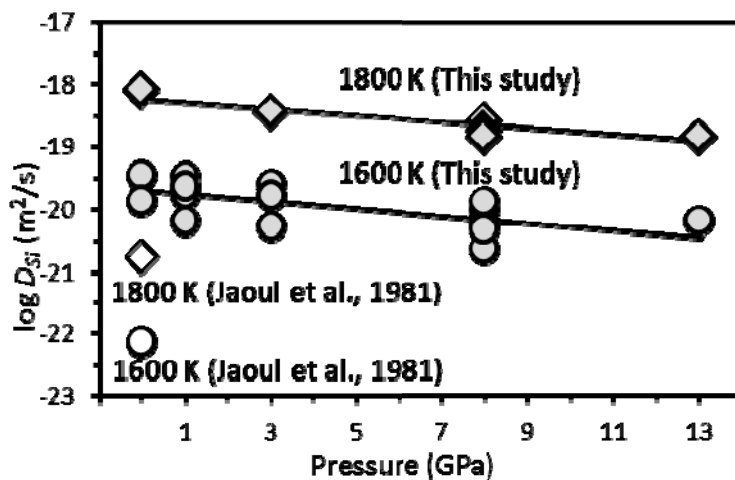


Fig. 3.6-10: Plots of $\log D_{Si}$ in forsterite against pressure at 1600 and 1800 K in comparison to data from Jaoul *et al.* (1981), *Anelasticity in the Earth*, **4**, 95-100.

Results of D_{Si} are plotted against pressure in Fig. 3.6-10. Our results are ~ 2.4 orders of magnitude higher than those measured by Jaoul *et al.* (1981) in forsterite at ambient pressure and 1-2 orders of magnitude higher than those in natural olivine (Fig. 3.6-11). In their studies, ZrO_2 thin film was not used for protecting the isotopic film. Possibly, without ZrO_2 , the isotopic film tends to horizontally shrink instead of diffusing into the substrate during high temperature annealing. Such phenomenon was found in some no- ZrO_2 coated samples with much shorter diffusion profile compare with normal ZrO_2 coated samples (Fig. 3.6-12). This phenomenon was not found in high-pressure experiments even without ZrO_2 film, which was not too surprising because the isotopic film was compressed by the surrounding material and well contacted with substrate at high pressures. Our data explain the high dislocation climb rates well and they solve the discrepancy of D_{Si} in olivine or forsterite measured in diffusion experiments and that estimated from deformation experiments.

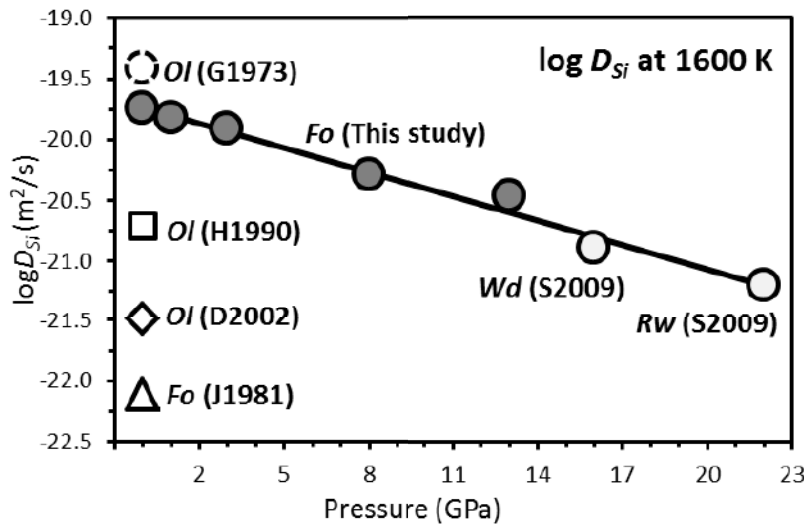


Fig. 3.6-11: $\log D_{Si}$ against pressure at 1600 K. *Fo*: forsterite. *Ol*: natural olivine. *Wd*: iron-bearing wadsleyite. *Rw*: iron-bearing ringwoodite. S2009: Shimojuku *et al.* (2009), *EPSL*, **284**, 103-112; H1990: Houlter *et al.* (1990), *PEPI*, **62**, 329-340; D2002: Dohmen *et al.* (2002), *GRL*, **29**, 2030-2034; J1981: Jaoul *et al.* (1981), *Anelasticity in the Earth*, **4**, 95-100. G1973: estimated from dislocation climb rate by Goetze and Kohlstedt, (1973), *JGR*, **78**, 5961-5971. D_{Si} from previous studies are all calibrated to 1600 K.

Olivine, wadsleyite and ringwoodite are the main constituents of the upper mantle. If we extrapolate our data of D_{Si} at 1600 K to higher pressures, it is almost equal to that in iron and water bearing wadsleyite and ringwoodite from published data (Fig. 3.6-11). The linear relationship of $\log D_{Si}$ with pressure in dry forsterite, iron and water bearing wadsleyite and ringwoodite implies that temperature and pressure would be essential factors that affect D_{Si} in comparison with other factors, for example, iron concentration, water content, and structural differences of the $(Mg,Fe)_2SiO_4$ polymorphs.

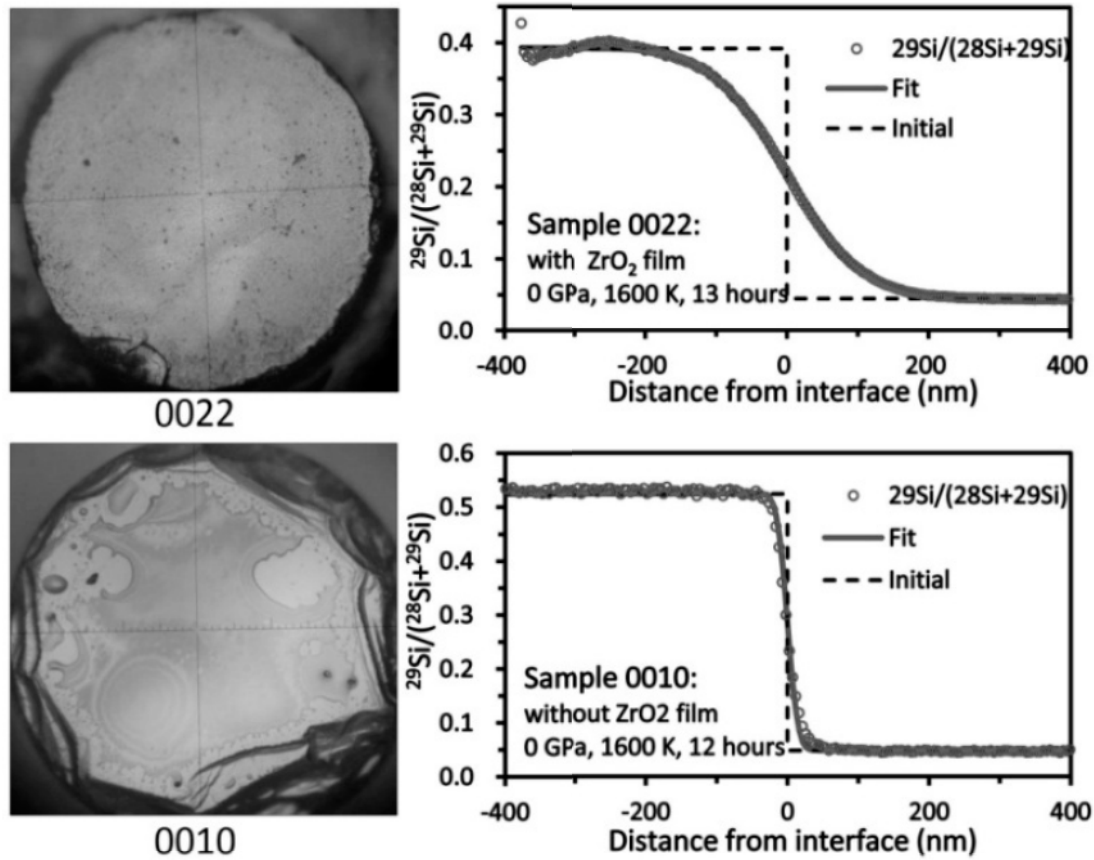


Fig. 3.6-12: Sample 0010 (1600 K, 0 GPa, 12 hours, without ZrO₂ film) and 0022 (1600 K 0 GPa, 13 hours, with ZrO₂ film). In sample 0010 the coated film shrank during the experiment yielding a diffusion profile much shorter than in sample 0022 which has the same pressure and temperature conditions and very similar duration.

f. *Major element diffusion in garnet in Earth's transition zone (W. van Mierlo, F. Langenhorst, D.J. Frost and D. Rubie)*

Majorite is a high-pressure polymorph of enstatite with a garnet structure, and forms a solid solution with the other natural garnets present in the Earth's mantle. It is thought to be the second most important phase in the Earth's transition zone, after the high-pressure polymorphs of olivine (wadsleyite and ringwoodite). Unfortunately, very little is known about the transport properties of this majoritic garnet phase. Especially the major element diffusivity in garnet plays an important role in understanding the dissolution kinetics of pyroxene into garnet in a subducting slab. Also after the oceanic crust has been subducted, it will form an aluminium inhomogeneity in the mantle. The diffusivity of the majorite component will here be of importance in controlling how long such an inhomogeneity can persist. Thus, we have conducted diffusion experiments on garnet diffusion couples to determine the major element diffusivity in the Earth's transition zone.